Calhoun: The NPS Institutional Archive

DSpace Repository

Theses and Dissertations | 1. Thesis and Dissertation Collection, all items

1986-12

A multimedia computer conferencing system.

Manley, James Edward

http://hdl.handle.net/10945/21988

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

Downloaded from NPS Archive: Calhoun

http://www.nps.edu/library

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

AL POSTGRADUATE SCHOOL
TEREY, CALIFORNIA 93943-5002

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A MULTIMEDIA COMPUTER CONFERENCING SYSTEM

by

James Edward Manley

December 1986

Thesis Advisor: Michael Zyda

Approved for public release; distribution is unlimited.

T230816

unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (If applicable) 52	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000	7b ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000
8a NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
A MULTIMEDIA COMPUTER CONFERENCING SYSTEM

12 PERSONAL AUTHOR(S) Manley, James Edward

13a TYPE OF REPORT Master's Thesis	13b TIME COVERED FROM _____ TO _____	14 DATE OF REPORT (Year, Month, Day) 1986 December	15 PAGE COUNT 87

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	multimedia computer conferencing; multicomputer network information-sharing; command and control systems; integrated office automation systems

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this study is to review the state of interworkstation computer communications, suggest ways in which these communications can be utilized for multimedia computer conferencing, and provide the details of a prototype system which demonstrates some of the capabilities that multimedia computer conferencing systems can have. The source code for the prototype system is provided in the appendices.

The results of this study are of interest to people designing command and control systems, integrated office automation systems, and personal and business communications systems. Additionally, the details of the multicomputer network information-sharing portion of the prototype can be useful to people who desire to distribute computational loads over a number o systems such as distributed graphics processing, scientific modeling and simulation, and engineering design and prototyping.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Prof. Michael J. Zyda	22b TELEPHONE (Include Area Code) (408) 646-2305 22c OFFICE SYMBOL Code 52Zk

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
unclassified

Approved for public release; distribution is unlimited.

A Multimedia Computer Conferencing System

by

James Edward Manley
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1976

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
December 1986

ABSTRACT

The purpose of this study is to review the state of interworkstation computer communications, suggest ways in which these communications can be utilized for multimedia computer conferencing, and provide the details of a prototype system which demonstrates some of the capabilities that multimedia computer conferencing systems can have. The source code for the prototype system is provided in the appendices.

The results of this study are of interest to people designing command and control systems, integrated office automation systems, and personal and business communications systems. Additionally, the details of the multicomputer network information-sharing portion of the prototype can be useful to people who desire to distribute computational loads over a number of systems such as distributed graphics processing, scientific modeling and simulation, and engineering design and prototyping.

TABLE OF CONTENTS

I. INTRODUCTION 9

A. EXISTING COMMUNICATIONS METHODS 9

B. MOTIVATION FOR MULTIMEDIA COMPUTER CONFERENCING 10

C. MULTIMEDIA COMPUTER CONFERENCING NOW FEASIBLE 10

1. Graphics Hardware 10

2. Audio Hardware 11

D. MULTIMEDIA COMPUTER CONFERENCING CAPABILITIES 12

E. OVERVIEW OF THE REMAINING CHAPTERS 13

II. BACKGROUND 14

A. RELATED COMPUTER DEVELOPMENTS 14

1. Hardware 14

2. Software 16

B. PREVIOUS WORK ON MULTIMEDIA COMPUTER CONFERENCING 17

C. STANDARDS 18

III. SPECIFICATIONS 20

A. FUNCTIONAL REQUIREMENTS 20

1. Network File Transfer Mechanism 20

2. Multitasking 21

3. Hierarchical Filing Structure 21

B. DESIRABLE CHARACTERISTICS 22

1. High-Resolution, Three-Dimensional Graphics 22
2. Flexible User Interface 22
3. Multiple Windows 23
4. Graphical Data Flow 23
C. HYPOTHETICAL MULTIMEDIA COMPUTER CONFERENCING SESSION 24
1. Activation of a Multimedia Computer Conferencing Session 24
2. Interaction Among Conference Participants 25
3. Intensive Two-Way Communications 25
IV. IMPLEMENTATION – COMMUNICATIONS PACKAGES 26
A. HARDWARE 26
B. COMMUNICATIONS NETWORK 27
1. Topology 27
2. Performance 27
C. SOFTWARE 27
1. Operating System 27
2. Communications Packages 28
a. Sockets 29
b. Client/Server Model 30
c. Using the Communications Packages in Applications ... 31
d. Details of the Communications Packages 33
(1) UNIX 4.2 BSD Communications Package 34
(a) Opening a Server Socket 34
(b) Opening a Client Socket 38
(c) Reading and Writing Data 39

(2) UNIX System V Communications Package 41
V. APPLICATIONS PROGRAMS 43
A. INTERTEXT 43
B. INTERDRAW 44
VI. LIMITATIONS AND CONCLUSIONS 47
A. LIMITATIONS 47
1. Synchronous Communications 47
2. Only Text and Graphics Media Currently Supported 48
B. CONCLUSIONS 48
1. Problem Areas 48
a. UNIX 48
b. Network Communications 49
c. Multicomputer Programming Tools 49
2. Recommendations 50
a. Standard Data Formats 50
b. Advanced User Interfaces 51
c. Enhancements to the Prototype Multimedia Computer Conferencing System 51
(1) Object Manipulation Applications 51
(2) Speech Recognition and Synthesis 52
APPENDIX A UNIX 4.2 BSD COMMUNICATIONS PACKAGE LISTING 53
APPENDIX B UNIX SYSTEM V COMMUNICATIONS PACKAGE LISTING 61
APPENDIX C INTERTEXT PROGAM LISTING 69
APPENDIX D INTERDRAW PROGRAM LISTING 72
LIST OF REFERENCES 84

BIBLIOGRAPHY 85
INITIAL DISTRIBUTION LIST 86

ACKNOWLEDGEMENT

I would like to thank my thesis advisor, Professor Michael J. Zyda, for his inspiration, guidance, and patience throughout the duration of this project. Without his assistance, this study would still be in progress.

I also want to recognize the programming assistance provided by Mr. Albert Wong of the Naval Postgraduate School Computer Science Department. His expertise in UNIX systems programming proved invaluable in making the prototype system a reality.

To the other Naval Postgraduate School faculty members whom I have studied under, I extend my warmest regards and gratitude for the help they have given me in better understanding the true meaning of scientific exploration.

Finally, I want to express my deepest appreciation and affection to Emma, my wife, for her understanding and the sacrifices she made to allow me to pursue this work. Her contributions were unquestionably the most important of all.

I. INTRODUCTION

A. EXISTING COMMUNICATIONS METHODS

Communication is an important capability for humans since it is the means by which we convey information and ideas, thereby expanding our knowledge, culture, and technology. Several means of communication are used by people in their daily activities including voice, writing, drawing, gestures, facial expressions, and body movements. These methods can be used either in person or over any distance via electronic media. Voice and writing can be disseminated by telephone and radio systems, and television can transmit all six communication methods. However, most people do not normally have access to television for personal communications. This is even more true in situations where information is to be originated by and shared between more than two people. Therefore, there are currently only three methods in widespread use that enable people to interactively share information: face–to–face, by telephone, and by teletype/computer terminals. However, the distance at which the first method can be used is limited to a few tens of meters, and the speed at which information can be transferred between people via the latter two methods is limited because of their inherently low bandwidths. Visually oriented communications contain a much higher bandwidth of information, but require correspondingly faster transmission channels such as television broadcast frequencies for acceptable real–time communications. Various methods to encode visual information for transmission over low–bandwidth media

have been developed, but the side–effects of the encoding processes and limitations in terminal hardware have resulted in low quality visual displays.

B. MOTIVATION FOR MULTIMEDIA COMPUTER CONFERENCING

During the past four decades, computers have become powerful tools used in one form or another by a large percentage of the world's population. The capabilities of these tools have increased incredibly and their accessibility has grown dramatically. Despite advances in individual computer power and the exponential growth in the number of computers in operation, the ability for people to easily communicate abstractions via different computers has not matured as rapidly. Many systems still use a line–oriented textual input/output mechanism used on the earliest computers even though the display medium has evolved from punched tape and cards to cathode ray tubes.

C. MULTIMEDIA COMPUTER CONFERENCING NOW FEASIBLE

1. Graphics Hardware

The development of low–cost, high–density processor and memory devices enabled the mass production of high–resolution bit–mapped raster graphics displays. Bit–mapped raster graphics allows both images and text to be displayed concurrently in any mixture, location, size, style, orientation and intensity or color on a display device. This visually–oriented capability allows the implementation of the window/icon/mouse concept, where programs, data, and devices can be represented by images in addition to text.

High–resolution bit–mapped graphics and advances in microprocessor technology provided the raw materials needed for the creation of graphics workstations and advanced microcomputers with performance equal to that of minicomputers. The integration of special–purpose coprocessors for floating point arithmetic, matrix manipulation, and video display into these systems has resulted in graphics processing performance unequaled by any other type of computer.

The advent of high–performance graphics workstations has made it possible to reduce the amount of communications bandwidth required to transfer high–resolution graphics information. Instead of transferring entire bit–mapped images frame–by–frame over networks, the graphics processing power of these machines allows just the characteristics of a graphics object to be transmitted while the receiving system can reconstruct the object very quickly, usually in less than one video frame interval (1/30th of a second). Once an object's characteristics have been received by a remote workstation, it is then possible to send commands to that workstation to translate, scale, and rotate objects. With this capability, it is possible for people to interactively manipulate graphics entities in real time.

2. Audio Hardware

Along with visually–oriented information formats, the ability to transmit audio information can be supported. Some microcomputers now possess the capability to digitize and reproduce sound very accurately as well as convert text to speech. With this added feature, it is possible to

implement a multimedia computer conferencing system which allows two or more people to quickly share audio as well as visual information.

D. MULTIMEDIA COMPUTER CONFERENCING CAPABILITIES

A multimedia computer conferencing system provides the ability for two or more people to share information in textual, graphic and audible form simultaneously. Textual and graphics information is displayed in windows on a workstation screen while audio information is produced through a microcomputer. Users can select objects on their display screens using a pointing device such as a mouse and cursor icon and perform operations on them such as translation, scaling, rotation and modification. These operations can be duplicated on other users' display devices in real–time and a number of users can manipulate objects in a window interactively to illustrate ideas. While graphics operations are carried out on objects, text typed by users can be converted to speech so that other users can watch the graphics while listening to a user's ideas. Digitized sound can also be transmitted as desired to enhance the realism or impact of graphics presentations. All of these actions can be recorded as they are produced or received so that all or any portion can be played back for people unable to participate in a live session or to study details more closely. These recordings can also be edited to improve a presentation, particularly if it is to be given at a later time to a large number of people in one or many locations.

E. OVERVIEW OF THE REMAINING CHAPTERS

This chapter provides an overview of general developments in computer hardware and software capabilities to date as related to workstation communications. Previous work in developing multimedia computer conferencing is discussed in the Background Chapter. The Specifications Chapter delineates the features that a multimedia computer conferencing system should have. UNIX interprocess and network communications are examined in the Communications Chapter. The components of the prototype multimedia computer conferencing system developed for this study are described in the Applications Chapter. The Limitations and Conclusions Chapter contains an explanation of the limitations of the prototype implementation, problems encountered in making the system work, and suggestions for implementing a full–featured system for real–world use. The Appendices provide the source code for the prototype, including the communications packages on which the prototype is based.

II. BACKGROUND

In this chapter we review the technological innovations which have made multimedia computer conferencing feasible today and discusses previous and ongoing work in the development of multimedia computer conferencing systems. Additionally, some information on the applicability of standards to this technology is provided.

A. RELATED COMPUTER DEVELOPMENTS

1. Hardware

Until the late 1970's, computers were so few in number and expensive that they were each generally shared among many people to perform primarily calculation–intensive computations or database storage and retrieval. One of the features of these systems was that it was usually possible for users to transfer information between each other since they were all running programs on the same system. As the number of computer systems slowly grew, it became desirable to interconnect them via communications networks so that information could be more easily and rapidly shared among geographically diverse people.

During the latter half of the 1970's, the first generation of microcomputers became available and, although their individual computational power was miniscule compared to their predecessors, they provided a level of functionality appropriate to the needs of most individuals. For those people who had frequent requirements to perform complicated or highly repetitive computations or who needed access to large

database systems, microcomputers could be connected to minicomputers and mainframe computers to have these tasks performed while input from and output to users were handled by the microcomputers.

At about the same time that microcomputers became widely available, the beginning of the 1980's, another new breed of machine appeared – the microprocessor–based workstation. Machines of this class provided a significant portion of a minicomputer's power for approximately four users at a small fraction of the price and size of the minicomputer. These workstations were also networked to allow information to be transferred quickly among distant users. However, all of the above–mentioned systems provided essentially the same types of functions to users in a multiuser, timeshared environment.

Even more powerful microprocessors such as the Motorola MC68010 and MC68020, each of which is capable of supporting a virtual memory address space up to four gigabytes in size, along with floating–point coprocessors and memory–management units, have made possible microprocessor–based workstations and microcomputers which surpass the capabilities of minicomputers designed and built through the late 1970's. Processing speeds well in excess of one million instructions per second and several million floating point operations per second are typical for these units.

In parallel with the above developments in computer power came important advances in the ways which information could be presented to and manipulated by computer users. Although special–purpose graphics displays had previously been utilized for output from minicomputers and

mainframe systems, they were almost exclusively used as secondary peripherals for the portrayal of graphics and some text (usually just labels). This was primarily due to the fact that most of these devices could not produce high–resolution images (at least 500 pixels horizontally by 300 pixels vertically) at a frame rate of at least 30 Hz (to prevent visible flicker). The tremendous reduction in cost of processor and memory devices starting in the late 1970's enabled workstation manufacturers to incorporate high–resolution bit–mapped raster graphics in their products.

The development of special–purpose integrated circuits during the past several years has dramatically increased the performance of computers, particularly microcomputers. These microcircuits can perform complex operations in parallel with the central processing unit thereby relieving the processor of many tasks and, in many cases, performing these operations faster than a general–purpose microprocessor. Special–purpose microcircuits now exist which perform such functions as floating–point mathematics, matrix mathematics operations, bit–mapped graphics block manipulations, text–to–speech conversion, digital–to–analog conversion, analog–to–digital conversion, and signal processing. By taking advantage of the advanced capabilities these devices provide, multimedia computer conferencing systems can be implemented with hardware which is very low in cost relative to conventional mini and mainframe computers.

2. Software

The realization of high–resolution bit–mapped graphics hardware set the stage for a revolutionary concept in computer input/output – the

graphics–based user interface. Researchers at the Xerox Palo Alto Research Center (PARC) and other institutions pioneered this advancement which centered around the window/icon/mouse philosophy. User interface designs with varying degrees of sophistication have since been implemented on numerous workstations and microcomputers. Some of these implementations only provide a desktop metaphor for file manipulation functions (copying, moving, deleting and executing files) and menus which provide assistance in selecting options within programs (e.g., Apple Macintosh). Other implementations include advanced environments in which programs can be interactively designed, implemented, and debugged (e.g., Interlisp). In all cases, the window/icon/mouse concept is a common feature which allows both novices and experts to operate any system without memorization of system–specific commands and names.

Windows can display file identities, the contents of files, the input and output of a program in execution, or other information as determined by the implementer. Another feature associated with this concept is the provision of pull–down or pop–up menus which aid users in selecting correct actions based on the context of a program's execution in a particular state, thereby reducing errors, training time, and the need to memorize command syntax.

B. PREVIOUS WORK ON MULTIMEDIA COMPUTER CONFERENCING

"Multimedia computer conferencing" is the term used by Sarin and Greif [Ref. 1] to differentiate current research projects such as MIT's RTCAL (Real–Time CALendar) and MBlink from earlier efforts at

"teleconferencing" by Bell Labs (Videophone) and others which used video or slow–scan television transmission techniques to achieve visual information sharing. Poggio, et al, [Ref. 2] describe a multimedia command and control computer conferencing system which is currently under development.

The problem of how to represent multimedia data is discussed by Aguilar [Ref. 3] and a recommended format is described. It is clear that in order for people at various sites to be able to conduct multimedia computer conferencing, standard formats are required to ensure consistency. The next section on standards provides some insight as to how difficult a problem this is. A great deal more work is needed in this area, but this issue is not the main focus of this study.

C. STANDARDS

Transferring textual information is very simple and can be performed on every computer system in widespread use because individual characters are mapped to integers using agreed–upon standard mappings. However, the exchange of graphics and audio data is much more complicated in that there are numerous ways of encoding the information and many of these possible methods have been implemented for various applications. There has been a great deal of work done in the area of developing standard methods of encoding graphics information in terms of fundamental elements and actions. After many years of proposals, discussion, and negotiation, only a standard for static, two–dimensional graphics (Graphics Kernel Standard – GKS) has been specified and agreed upon by international consent within the International Organization for Standards

(ISO) and the American National Standards Institute (ANSI). An extension of this standard which maps two–dimensional objects into three dimensions (GKS–3D) has been under way for the past few years, but it is also designed for transmission of static representations. Other standards are being developed which are intended to enable programmers to write programs which are graphics device independent (Computer Graphics Interface – CGI, Virtual Device Interface – VDI, and Computer Graphics Metafile – CGM) so that graphics generated on one system can be accurately recreated on other systems to the maximum capabilities of their display devices. Also, a means of interactively manipulating large graphics object databases (Programmers Hierarchical Interactive Graphics System – PHIGS) is being developed. Of these standards, PHIGS is most closely related to the development of multimedia computer conferencing systems since it is concerned with the representation and interpretation of complex and dynamic graphics objects independent of their origin and intended use, as described by Shuey and Bailey [Ref. 4]. These standards have not been widely implemented because most have not been fully defined or approved by the members of the standards organizations. Also, many potential implementers such as Herman [Ref. 5] feel that the standards exact too high a price on performance. Since performance is usually a much more important factor than compatibility in current applications, there has not been enough incentive to implement these standards to date. Additional improvements in processing power, possibly using multimicroprocessor architectures, may be necessary before these standards can be widely used.

III. SPECIFICATIONS

In this chapter, we describe the types of features multimedia computer conferencing systems should have, from both a communications standpoint, i.e., what functions must be provided, and a user's standpoint, i.e., what features would people like to have. Some of these functions and features are implemented in the prototype multimedia computer conferencing system described in the next two chapters.

A. FUNCTIONAL REQUIREMENTS

In order to determine what features a computer conferencing system should have, it is useful to examine the communications capabilities available on current systems and decide what attributes need to be modified, expanded and added to improve those capabilities.

1. Network File Transfer Mechanism

Most systems in use today provide at least one fundamental means of communicating with people on other computers: a file transfer mechanism via network communications. This mechanism enables users to send and receive files via a network. Some systems provide an on–line message composition facility, usually called electronic mail or E–mail, so that people can carry on a conversation in real–time on a local area network, or with varying degrees of delay on a widely distributed network such as the Department of Defense Advanced Research Programs Agency ARPANET. However, electronic mail is a text–oriented medium since that is the form in which computer–related information has historically been

generated and transferred, particularly because of limitations in wide–area network communication bandwidths. As a result of the existing information transmission systems being text–based and network communications having low bandwidths, there has not been much incentive to attempt to establish graphics–oriented communications systems. The development of high–performance graphics workstations and microcomputers, however, now makes it possible to implement integrated text, graphics and audio–oriented communications at any location which has access to a network communications system.

2. Multitasking

Another desirable attribute of a computer conferencing system is workstation multitasking so that users can receive information on their displays from more than one remote user or program simultaneously. This capability is especially important if audio information is to be sent along with corresponding visual information so that the two types of media remain synchronized when delivered to users.

3. Hierarchical Filing Structure

Another feature which a computer conferencing system workstation should possess is a hierarchical filing structure which enables users to efficiently organize files and allows them to be referenced singly or in groups with meaningful names. This makes transfer of related files (or hierarchically–organized multimedia objects) very simple because a single name can be used to identify many files (or objects) in a subtree to be sent over a network.

B. DESIRABLE CHARACTERISTICS

1. High–Resolution, Three–Dimensional Graphics

In order to accommodate the widest possible range of applications, the graphics output devices used in a multmedia computer conferencing system should support real–time, high–resolution, three–dimensional color graphics. The development of powerful microprocessors and high–speed, high–density memory circuits has made it possible to design and build special–purpose microprocessor–based systems which can perform three–dimensional floating–point calculations, map the results to memory, and transfer the contents of memory to display devices such that thousands of polygons can be drawn in a single frame and displayed at normal television frame rates (30 to 60 frames per second).

2. Flexible User Interface

An important feature of any modern computer software, particularly for communications, is a well–designed user interface. The bit–mapped raster graphics inherent to graphics workstations and microcomputers makes implementation of graphics–based user interfaces straightforward. Graphics–based user interfaces have been criticized as being not powerful enough and are only suitable for unsophisticated computer users, but if an interface is consistent, intuitive, and flexible, it will meet the needs of both neophytes and experienced users. Even experts can benefit from menus and graphic metaphors when using a system with which the user is not familiar. Pop–up menus do not prohibit the support of keyboard equivalent commands for proficient users.

3. Multiple Windows

A means for organizing communications between users and programs should be provided. Graphics–based user interfaces enable intuitive–to–use and meaningful representations of data flow to be used. For example, a window can be provided for each communications link between a user and another user or program on a remote system. This enables a user to monitor and interact with as many other users and programs as can be displayed on the screen. Each window can display text or graphics or any combination of the two. The number of reasonably–sized windows which can be displayed on a typical workstation screen is about a half a dozen if they are not allowed to overlap. Using overlapping windows this number can easily be a dozen or more.

4. Graphical Data Flow

Graphics–based user interfaces can also provide a means to visually display communications paths between programs and/or computers. On UNIX systems, these paths are referred to as "pipes" within a single computer system, and "socket connections" between two or more computer systems. Pipes and socket connections can be graphically portrayed using line segments to connect icons representing programs and computers. In this way, a user can easily establish and terminate communications paths with other users, between programs, or between himself and programs running on other computer systems.

C. HYPOTHETICAL MULTIMEDIA COMPUTER CONFERENCING SESSION

1. Activation of a Multimedia Computer Conferencing Session

A multimedia computer conference can be scheculed by a moderator or chairman announcing the name and time of the conference via electronic mail. If new data elements and objects are to be presented by individuals during the conference, these can be requested by other interested participants via electronic mail and transmitted before the scheduled time of the conference. At the announced time of the presentation, the moderator opens a channel to allow interested network users to begin connecting to the conference. A participant only needs to specify the standard name of the system and the name of the presentation in order to establish a connection. Presentations by speakers can then take place by broadcasting sequences of commands and data which specify visual and audio objects and the operations to be performed on those objects. These sequences can be recorded by conference participants for playback at a later time to either allow people to see and hear presentations who were not able to do so during the conference, or to enable closer examination of particular portions of the conference. Also, if two or more conferences are in progress at one time, users can participate in one while recording others. It should be noted that the amount of storage required to save conference proceedings would be significantly less than currently–used techniques because the object definitions and command streams are compact.

2. Interaction Among Conference Participants

During a presentation, users can locally manipulate objects in their windows at the same time that the presentation is taking place so that they can examine an object as their needs dictate. Also, feedback from other participants can be received in a window on the presenter's system, thus allowing clarification of difficult concepts or altering the flow of the presentation to accomodate differences in the expectations of the presenter and the audience in terms of familiarity with the subject matter.

3. Intensive Two–Way Communications

Although this system is oriented toward conferencing among a number of users, it is also useful for one–on–one sharing of information. In this manner, two people can carry on an interactive dialog using text, graphics, and sound to exchange ideas. Several windows can be utilized in such a conversation, each containing information related to the subject being discussed. For example, engineers can have a mechanical drawing displayed which they are both editing and the results of changes to the drawing can be displayed in another window as a shaded three–dimensional perspective object defined by the drawing, while another window displays material lists and another shows cost data. Another example is a command and control application where a military commander can monitor numerous sensor and information windows, zooming in certain windows to obtain more detailed information about critical areas while retaining an overview of a situation in other windows.

IV. IMPLEMENTATION – COMMUNICATIONS PACKAGES

Using the specifications developed in the last chapter as a guide, a rudimentary prototype multimedia computer conferencing system was developed with hardware and software available within the Graphics and Video Laboratory of the Naval Postgraduate School's Department of Computer Science. It is emphasized that the purposes of developing the prototype were to determine what elements were necessary to provide a minimal set of capabilities for multimedia computer conferencing and to gain experience with a simple system to assist in determining what attributes a full–scale implementation for real–world use should have. The prototype is not meant to represent a fully–developed system as there are many more details which would have to be realized than are dealt with in the prototype. The specifications are a set of desired features, not all of which are provided by the prototype. Communications packages for UNIX 4.2 BSD and UNIX System V are explained in this chapter.

A. HARDWARE

Computer systems used in the prototype were a Digital Equipment Corp. VAX 11/785, two Silicon Graphics, Inc. IRIS 2400 workstations, and a group of eight networked Integrated Solutions, Inc. Optimum V workstations.

B. COMMUNICATIONS NETWORK

1. Topology

A central Xerox Ethernet network connects the following systems which are located within the Computer Science Department at the Naval Postgraduate School: a VAX 11/785, a VAX 11/780, a VAX 11/750, two IRIS 2400 3–D color graphics workstations, an ISI Optimum V black–and–white workstation, and two Intel Multibus 8086 multiprocessor microcomputer systems. The ISI workstation is connected to seven other ISI workstations via its own Ethernet network, but any of the ISI workstations can connect to systems on the central network by passing messages through the ISI workstation on the central network.

2. Performance

The Ethernet networks communicate serial packets of data at a maximum transfer rate of 10 megabits per second. Due to the large number of programs and users which may be accessing the network at any given time, the transfer of data over the network frequently slows down perceptibly.

C. SOFTWARE

1. Operating System

The operating system used for the prototype multimedia computer conferencing system is UNIX. UNIX meets all of the criteria stated in the specifications with regards to multitasking, hierarchical file structure, and support for network communications. The most significant strength of UNIX is that it has been implemented on many models of production minicomputers and workstations, including those available for this

implementation. UNIX is a very popular operating system in academic institutions because of its low cost, particularly 4.2 BSD. In addition to its technical merits, the operating system source code is generally provided with UNIX. Commercial users and government agencies rely on UNIX for research and development because of the wealth of tools which have been produced for it and the extensive base of software which has already been written.

Of note, while the VAX and ISI systems are supported by the UNIX 4.2 BSD operating system, the IRIS workstations currently utilize AT&T UNIX System V. There are a number of subtle but important differences between these two versions of UNIX, especially in the way network communications are implemented. Some of these differences are discussed in the following section.

2. Communications Packages

A communications package forms the core of the implementation of the multimedia computer conferencing system. Application software generates data which is then transferred through the communications package, or receives data from the communications package and performs operations on it which results in the display of text and graphics on a workstation. Two different versions of the intersystem communications package had to be written to allow programs running on the IRIS workstations to communicate with programs running on the VAX and ISI systems due to the different versions of UNIX implemented on these systems. The communications package is general–purpose in nature and so can be utilized for building other distributed–computer processing

applications. Computation–intensive problems such as ray–tracing, realistic rendering of lighting and shading, generation of fractals, scientific modeling, and engineering simulation can all readily take advantage of such distributed processing. The C source code for the implementation of communications functions under the two operating systems is contained in Appendices A and B.

The remainder of this section includes an overview of intercomputer communications using the UNIX operating system, discusses the use of the communications package functions in applications, and describes the operation of the communications packages.

a. Sockets

The fundamental method for communicating between UNIX systems is the socket mechanism. A socket is a logical entity which represents the details of a connection between a given UNIX system and another remote UNIX system. For each connection between two systems, there are two sockets dedicated to that connection, one on each system.

On a particular system, each socket has associated with it a logical port number, network system name and logical address, network address family type, and logical descriptor numbers for local and remote sockets. The logical port number is an arbitrarily chosen integer which must be larger than any of the system's reserved port numbers (typically, the first 1024 port numbers are reserved by the superuser for implementing such entities as user login connections, pipes, and file transfer connections). The port number must be the same for the sockets associated with the single connection between any two systems. The network address

family type is an integer constant which defines the network protocol used in connecting a group of computer systems, such as Internet, IBM SNA (Systems Network Architecture) and International Organization for Standardization (ISO) CCITT. The network system name and address are complementary data items which are stored in a system lookup table. Providing the system with either piece of information enables the system to determine the alternate value. Usually, a user knows the system name. A function is used to convert the name to a network address which is then used to establish a connection between two systems. The connection is identified in the form of a logical socket descriptor (number). The logical socket descriptors are integers which are returned by function calls when a socket is opened or a connection to another socket is established.

b. Client/Server Model

UNIX uses a client/server model in the establishment of communications between two or more systems. A server is considered to be a process that exchanges information with one or more remote client processes over a single socket connection. A client is defined as a process that shares information with a server via a single socket connection.

The general sequence for establishing a connection between two UNIX systems is as follows (details of the function calls are discussed in the next section). Each entity places its respective local socket parameters into a socket address structure, then opens a local socket using those parameters in a function call. Of note, the socket port number must be the same on both systems. Once the server process has opened a socket, it calls a function to accept connections. At this point, execution of the process is

blocked until a client process connects to the server socket. Meanwhile, a client process can attempt to connect its socket to a remote server by calling a connect function. If the client attempts to connect to a server which is not yet ready to accept connections, then the connect function returns an error number indicating that the connection was refused. The client needs to close its local socket, open a new one and continue attempting connection until the server accepts its connection.

c. Using the Communications Packages in Applications

For applications programmers, the C source code for the communications packages to perform the connection of a server to a client and a client to a server is in Appendices A and B. This code should be compiled to a relocatable object file. It should be stored in a library on each system it will be used on so that it can be linked into any application which requires intersystem communications. Within an applications program, if the program will be initiating communications as a server, it must call the connect_server() function providing the name of the remote client system in a string pointed to by remote_client_name and the logical port number through which communications are desired in the integer parameter port_number.

```
char *remote_client_name;
int   port_number;
int   local_socket;
          ...
local_socket = connect_server(remote_client_name, port_number);
```

The server program then waits for a client program to connect before proceeding. Another program running on another system, acting as a client, can then connect to the server by calling the connect_client() function using the address of the remote_server_name and the same port number used by the server program.

```
char *remote_server_name;
int   port_number;
int   socket_number;
          ...
socket_number = connect_client(remote_server_name, port_number);
```

To write data to a socket, the write() function is called with the socket number of the remote system connection, a pointer to a buffer (the address of the variable or data structure in which the data to be transferred is stored), and the number of bytes which are to be transferred (use the sizeof() function with the type or name of the variable or data structure as a parameter). Note that the variable used in the example is a character array, but any type of variable or data structure can be used. The write() function returns the number of bytes actually written so that it can be determined whether a problem occurred in writing to the remote system.

```
int socket_number, number_of_bytes;
char *buffer_pointer;
int bytes_written;
          ...
bytes_written = write(socket_number, buffer_pointer, number_of_bytes);
```

A problem with the write() function is that it is synchronous – that is, it suspends execution of a program it is called in until the remote system has read the data it sent. If data needs to be sent without interrupting the applications program, the write_immediate() function provided in the communications package can be called using the same parameters as write(). The write_immediate() function is asynchronous – it creates a separate sequence of code which executes in parallel with the applications program.

Reading data from a socket is equally straightforward using the read() function.

```
int socket_number, number_of_bytes;
char *buffer_pointer;
int bytes_read;
        ...
bytes_read = read(socket_number, buffer_pointer, number_of_bytes);
```

Unfortunately, the read() function, like the write function, is also synchronous and execution of a program it is called in is suspended until the remote system has written data to the socket connection. An attempt was made to create an asynchronous read function, but the nature of UNIX interprocess communications and the lack of time for this effort has made it a future improvement.

d. Details of the Communications Packages

This section describes the details of the communications establishment packages for systems programmers. Although UNIX 4.2

and UNIX V provide essentially the same functionality, there are significant differences in the syntax of the parameters to their library functions which can make it difficult to establish interprocess communications between two or more systems, each using a different flavor of UNIX. As a result, two versions of the socket communications establishment code were written for the prototype multimedia computer conferencing system, one for each type of UNIX system. In particular, the UNIX socket(), accept() and connect() functions use different numbers of parameters in incompatible orders! Additionally, UNIX 4.2 requires the use of the bind() and listen() functions while System V does not possess counterparts to these functions. It is helpful to have the system include files sys/types.h, sys/socket.h, netinet/in.h, and netdb.h from the /usr/include/ directory available during this discussion. The UNIX 4.2 implementation is discussed first, followed by that for System V.

(1) UNIX 4.2 BSD Communications Package. The sequence for establishing connection of UNIX systems via sockets occurs in two parts. A program on a given system is considered a server whose name and location is known to other systems. The programs which attempt to connect to the server program are thought of as clients. The normal course of events is for the server to establish itself on its system and client programs then attempt to connect to the server.

(a) Opening a Server Socket. In order for the server to establish an Internet socket on its system, a logical port number, address of the remote system, and protocol family type must be placed into an Internet

socket address data structure of type sock_addr (see the system file /usr/include/netinet/in.h for details about the in_addr data structure).

```
struct sock_addr_in
                {
                short   sin_family;
                u_short sin_port;
                struct  in_addr sin_addr;
                char    sin_zero[8];
                };
```

The port number must be above the ports reserved by the system, which are typically 0 – 1023 on a VAX. The address of the remote system can be obtained by calling gethostbyname() and providing a double–indirected pointer to a character array (string) containing the name of the remote system. The sequence in Figure 1 demonstrates how to prepare the parameters which are passed into the socket() function. The socket() function is called with the address family (AF_INET for Internet), the type of data transfer sequence (SOCK_STREAM – data packets delivered in the order sent, or SOCK_DGRAM (datagram) – data packets delivered as they arrive) and the protocol for the communications network (if zero is passed to the function, the default protocol for the local system is used, which is TCP/IP on the Naval Postgraduate School Computer Science Department's computers).

```
int local_socket;

local_socket = socket(AF_INET,SOCK_STREAM,0);
```

If for some reason a socket cannot be established, the socket() function returns a value of minus one. This usually happens because the port number selected is already in use by another program or the name or address of the remote system is not known to the local system. If the socket

```
struct sockaddr_in address;

char *remote_name;

long remote_address;

int remote_port;

int address_size;

ptr_remote_name = &remote_name[0];

remote_address = (long)gethostbyname(&ptr_remote_name);

/* initialize the remote system port number above the system reserved
   ports */
remote_port = IPPORT_RESERVED + 1;

/* add the user's port number to the remote port number  */
remote_port = remote_port + user_port;

/* remote client system address family (Internet in this case) */
address.sin_family = AF_INET ;

/* place the remote client port number into the socket address data
   structure */
address.sin_port = remote_port;

/* put the port number in network byte order */
address.sin_port = htons(address.sin_port);

/* place the remote system's address in the socket address data
   structure */
address.sin_addr.s_addr = remote_address;

/* find the number of bytes in the remote client address */
address_size = sizeof(remote_address);

/* place the remote system address family (Internet in this case)
   into the socket address data structure */
address.sin_family = AF_INET ;
```

Figure 1 Preparing for a call to the socket() function.

cannot be established using the provided parameters, the program must change the appropriate parameter and attempt to obtain a socket again. If the remote system address is correct, then all that is normally necessary is to change the logical port number to a different value. If the call to the socket() function is successful, it returns a positive integer, the socket descriptor. A socket descriptor is used in the same manner as a file descriptor is used when writing and reading data to and from files.

In UNIX 4.2, once a socket has been obtained on the local system, the Internet socket address data structure must be bound to the socket using the bind() function. The socket number, a pointer to the socket address data structure (type–cast to type caddr_t, which is a character pointer) and the number of bytes in the structure are passed to bind().

```
int bind_result;

bind_result = bind(local_socket, (caddr_t)&address, sizeof(address));
```

The bind() function returns a positive integer to indicate it was successful and a negative integer if it was not. Once the socket address data structure is bound to the socket, the maximum number of clients which can be connected to the server at one time must be designated via the listen() function.

```
listen(local_socket,5);
```

An integer value between one and ten is typically used for the maximum number of clients to limit the impact on other processes being executed on a system.

The accept() function is used to initiate the connection of the local socket to a remote system socket with the same port number. The

local socket number, a pointer to the socket address data structure, and a pointer to the number of bytes in the data structure are provided to accept(). At this point, execution of the program is suspended until a remote client system connects to the server system. When a connection is established, accept() returns a positive integer representing the remote system socket number which is used henceforth to refer to the connection for reading and writing data.

```
remote_socket = accept(local_socket, &address, &address_size);
```

Once a socket has been obtained, bound, and is listening in UNIX 4.2, the server socket is ready to accept connections from remote systems. This is accomplished by passing the local server socket descriptor, address family type, and options to the accept() function, which returns a socket descriptor for the remote system when a connection has been established. It is important to know that the accept() function blocks execution of the process in which it is called, so that if it is in the main sequence of execution in a program, the program will halt until a connection with a client program on another system is established.

(b) Opening a Client Socket. The client program executes a sequence almost identical to that of the server program to establish a local socket and connect to the server's socket. The socket() function is called to obtain a local socket, using the same parameters as the server did, until a valid positive integer socket number is returned. Neither bind() nor listen() are used by client programs since they can only access one server at a time. The client then calls the connect() function with its local socket descriptor, address data structure, and number of bytes in the structure.

```
remote_server_socket =
    connect(local_socket, (caddr_t)&address, sizeof(address));
```

Although the remote server system socket number is returned, the client program must refer to this connection for reading and writing data by its local socket number. This is in direct opposition to the server, which refers to the connection by the remote socket number it received from accept().

(c) Reading and Writing Data. At this point, the accept() function in the server allows execution to resume, and a communications connection has been established between the server and client programs. This connection is two–way in nature, so that data can be transferred in either direction. However, the UNIX functions which send and receive data, the write() and read() functions, respectively, also block execution of a program in which they are called until each data transfer is complete. A method that can be used to circumvent this problem in the program sending data is to start a child process with the fork() function and make the call to the write function within the child process. This allows the program sending information to continue execution even if the write() function call is blocked. The write_immediate() function in the communications package performs this operation.

```
write_immediate(socket_number, buffer_pointer, nbytes)

    /* socket number to be written to */
    int socket_number;

    /* buffer of bytes to be written */
    char buffer[];

    /* the number of bytes to be written */
    long nbytes;
```

```
{

/* function which initiates a child process */
int fork();

/* value returned from routine fork()  */
int forkval;
```

First, initiate a child process which will perform the write operation.

```
forkval = fork();
```

Next, determine if a child process was started and if so, begin writing data.

```
/* check to ensure a zero was returned by fork() indicating a child
   process was started */
if(forkval == 0)
   {
   while(write(local_socket,buffer,nbytes) != nbytes)
      {
      /* perform the write operation */
      }
```

When the data has been written, terminate the child process.

```
   exit(1);
   }
```

Otherwise, return an error value to the application indicating that the child process was not successfully started and therefore the data was not written.

```
else
   {
   return(-1);
   }
return(forkval);
} /* end of function write_immediate() */
```

If the write was successful, the value of the forked process is returned to the application program to indicate the successful write operation.

An attempt was made to create an asynchronous read_immediate() function, but the absence of an interrupt–driven interprocess communications capability in UNIX prevented the achievement of such a function. The designers and implementers of UNIX 4.2 BSD at the University of California at Berkeley have considered providing such a feature, but have not yet done so. In the meantime,

further research into the implementation of an asynchronous read function is needed, possibly utilizing semaphores or another low–level operating system mechanism.

(2) UNIX System V Communications Package. The communications package for UNIX System V is very similar to that for 4.2 BSD, so only the differences will be explained. The acquisition of a local socket for clients and servers under System V is the same as that for 4.2 BSD with a few exceptions. First, the System V rhost() function is called instead of the 4.2 BSD gethostbyname() function to convert a system name to its network address. The same double–indirected pointer to the name is used as an argument.

```
remote_client_address = rhost(&ptr_client_name);
```

Calling the socket() function in System V is different than calling socket() in 4.2 BSD. The type of data packet delivery (SOCK_STREAM or SOCK_DGRAM) is passed as the first parameter. Next, the protocol type structure is passed, which must be type–cast to the sockproto structure if the default value of zero is used. Note that a significant difference in the System V socket() function call is that a pointer to the Internet socket address data structure is passed to the socket() function directly as the third parameter. This is the reason that there is no bind() function in System V like that in 4.2 BSD. Finally, an options parameter that is unique to System V is provided which specifies how the socket is to be maintained in case an attempt to accept a connection fails.

```
int local_client_socket;

 local_client_socket =
    socket(SOCK_STREAM, (struct sockproto *)0, &address, options);
```

Once a local socket is established, a connection can be accepted by a server or connect() can be called by a client program. In both cases, the local socket number and a pointer to the Internet socket address data structure are passed as parameters and an integer representing the remote socket number is returned. If the value returned is less than zero, an error occurred in the accept() or connect() call. In that case, the local socket should be closed with a call to close(local_socket) and another local socket should be opened before calling either accept() or connect().

```
remote_client_socket = accept(local_socket, &address);

                       or

remote_server_socket = connect(local_socket, &address);
```

If the remote socket number is non–negative, then the connection has been established and in both cases the local socket number is returned to the applications program. This is yet another difference from 4.2 BSD because in that system the remote socket number must be used to refer to the socket after accept() is called, while the local socket number is only used after a call to connect().

V. IMPLEMENTATION – APPLICATIONS PROGRAMS

Two applications programs were written to demonstrate the potential capabilities of a multimedia computer conferencing system. Each program demonstrates how information from a single medium such as text or graphics can be transferred. Source code listings for the programs are located in Appendices C and D.

A. INTERTEXT

Intertext is a very simple program which allows two users to establish a connection between themselves using workstations for the exchange of messages. When the program is started, the user is asked whether a session is being started by himself or another user. If the user is originating the session, a system name and port number are asked for, the program starts the connection process and notifies the user that it is waiting for the remote user to connect. If the user is completing a connection to a session already originated by a remote user, the program requests the remote system name and port number and notifies the user when the connection is complete. The user who originated the session should type in a messge first (messages are sent by pressing the "return" key). The message is printed on the remote user's screen and then a response can be sent from the remote user in a similar manner. A session is terminated by either user sending a message which begins with a lowercase 'q'. If for some reason an attempt to establish a connection fails, the program can be run again using a different port number. Users should

set aside a block of port numbers to be used for Intertext sessions and notify remote users which port number to use by another means such as electronic mail.

The IRIS workstations support up to ten windows on a screen at one time and any number of these can be Intertext program windows, so that conversations can be had with up to ten other users at one time. The ISI workstations have a similar capability. The terminals connected to the VAX systems are text–only display devices and can therefore support only one conversation at a time.

Note in the Intertext listing in Appendix C that only one call to the communications package is made, either to connect_client() or connect_server(), to establish the connection. Simple read() and write() function calls transfer the data and close() is used to terminate the connection.

B. INTERDRAW

Interdraw is a graphics program which allows two users to simultaneously draw straight line segments in one window on each of their graphics workstations. The startup procedure is the same as that for Intertext, with one user being the initiator and the other the responder. After a connection is established, a window is opened on each workstation screen. To draw in the window, the right mouse button is pressed to activate the window. If the mouse is moved, the cursor in the window will follow its movements up, down, left, and right and a "rubber band" line segment will be drawn from the center of the window to the cursor. Pressing the middle mouse button will cause the "rubber band" line

segment to be drawn from the current cursor position. Pressing the right mouse button will draw a permanent line segment from the last place it was pressed to the current cursor location. Each user's line segments are displayed in red on his local workstation while the remote user's line segments are displayed in blue.

As shown in the listing in Appendix D, like Intertext, the only call that Interdraw makes to the communications package are to connect_client() or connect_server(). Once communications are started, the programs alternately call write() and read() functions to send and receive commands and positional data. This information is organized in each transmission in a data structure which holds three floating point or equivalent–sized values. The first value is the action to be taken (no action, draw a new line segment, or move the starting point of the next line segment) and the remaining two values are the x and y coordinates in world space, respectively. In other applications, a more complex data structure can be devised and all that is necessary to send or receive the data is to call the write() function with a socket number, the address of the data structure (a pointer), and the number of bytes in the data structure (using the sizeof(structure–name) function).

Interdraw can be used in parallel with Intertext for a multimedia conferencing session on a multitasking workstation such as the IRIS with each program executing in its own window. This combination demonstrates one of the most important features a multimedia computer conferencing system can offer – interactive information sharing, where people can easily use drawings to convey their thoughts and amplify textual

descriptions. Just as scratchpads, chalkboards and cocktail napkins have been used to make important ideas clear, Interdraw allows people to communicate more effectively.

VI. LIMITATIONS AND CONCLUSIONS

The prototype multimedia computer conferencing system developed in this study demonstrates the feasibility of implementing such a system using existing software and hardware. It is a prototype and therefore does not possess all of the qualities desirable in a full implementation. However, the basic capabilities can be expanded as needed to improve its ability to support transfer of information with existing information processing systems. The following sections discuss some of the systems current shortcomings and recommended avenues for future exploration in the area of multimedia computer conferencing.

A. LIMITATIONS

1. Synchronous Communications

The prototype implementation is somewhat hampered by the synchronous nature of the UNIX interprocess and network communications facilities. Applications must be designed so that users must know whether they are executing the program as a server or a client. If the users at two sites do not properly coordinate the activation of their programs, a connection is not established and the programs must be reinitialized. The synchronization requirement also dictates that both entities on a connection perform a read/write transaction before the program segments they are executed in are allowed to continue execution. This problem can be eliminated by the development of an asynchronous read() function. This is possible to achieve using the shared memory

feature of UNIX System V which allows two or more processes to read and write data in memory on a single processor asynchronously. An asynchronous read() function can most likely be implemented under 4.2 BSD using low–level operating system functions.

2. Only Text and Graphics Media Currently Supported

The Specifications chapter discussed the desirability of transferring audio information during a conference. Although not as significant as text and graphics, this is an important feature and should be provided in a full–scale system.

B. CONCLUSIONS

1. Problem Areas

a. UNIX

Using UNIX as the operating system for multimedia computer conferencing presented some problems. Although the socket mechanism is described in the UNIX documentation as having the ability to connect multiple clients to a given server through one port, no more than one client could be connected to a server at one time through one port on the prototype system. To circumvent this problem, conference server programs have to open a socket for each client which desires to connect to that conference. This consumes more sockets and makes the connection operation much more complicated than would otherwise be necessary. Another problem with UNIX sockets is that the client/server model on which socket connections are based is asymmetric and synchronous, that is, it forces a server program to suspend execution until a client connects to it and processes cannot continue execution until data written by one process is

read by another and vice versa. An interrupt–driven means of exchanging data would be very useful and, although such a capability has been considered by the designers of UNIX, it has not been specified or implemented yet.

b. Network Communications

The central Ethernet network which connects the computer systems together is adequate for file transfers and electronic mail between systems. However, because of the large number of users which work on the systems connected to the network, data transfer rates for programs which are communications–intensive slow down perceptibly when waiting for data. Also, some data was lost, even when the UNIX SOCK_STREAM guaranteed sequential packet delivery option was used. These problems indicate that multimedia computer conferencing should be conducted over communications channels which are not used for large–scale data transfer operations, if possible. Due to the effective data compression possible with multimedia computer conferencing systems, it may be feasible to use dedicated lower–speed communications channels for this purpose.

c. Multicomputer Programming Tools

In any type of programming, powerful tools can make designing, implementing and testing programs much more effective. As in most software environments, the tools available to people working on multimedia computer conferencing systems are inadequate. It is difficult enough to debug a program on a single computer system – it becomes extremely difficult to debug a number of programs executing on two or more computer systems, particularly if they are physically separated by more than a few

feet. Many hours were spent during the development of the prototype attempting to isolate the causes of problems. Frequently, it was not possible to determine which system an error was occurring in and only time–consuming trial–and–error techniques resulted in isolation of some problems. Future work in multimedia computer conferencing will require more advanced programming tools in order to achieve advanced capabilities in these systems. In particular, multisystem debugging aids are needed to help alleviate the problem of isolating errors to a single system and individual program. Information about what data has been transmitted and received and the sequence in which the data was transferred is very important and not readily available with current tools.

2. Recommendations

For systems software engineers who are developing multimedia computer conferencing systems, there are some recommendations which result from the experience of implementing and using this prototype.

a. Standard Data Formats

One of the primary limitations of the prototype developed in this thesis is the rudimentary set of data formats used to identify various types of data such as text and graphics. In a full–scale implementation, a much larger set of formats would be necessary to hierarchically define subtypes of data such as graphics primitives and objects. Some work has already been done by Aguilar [Ref. 3] in developing data formats suitable for use in multimedia computer conferencing. Eventually, a standard set of data formats will have to be agreed upon if multimedia computer conferencing is to become a widely used. The standards process is a long and complex

one which takes years to traverse. One of the keys to early, widespread implementation of multimedia computer conferencing will be provision of a capability to expand the standard since it is extremely difficult to forsee the requirements which will be placed on such systems in future years.

b. Advanced User Interfaces

With the proliferation of hardware and software which provide advanced user interface features, it has become clear that there is more to an effective user interface than windows, menus, and mice. Many systems that are equipped with a graphics interface do not provide a full set of programming tools to allow applications programmers to customize. A number of systems such as the Apple Macintosh, Commodore Amiga, Atari ST, and Digital Research GEM environment have "toolboxes" containing hundreds of routines for user interface functions that can be called from any programming language implemented for the system. These routines make implementing user interface features in programs much easier and more consistent since the programmer doesn't need to build them from scratch. If all systems had a rich set of such routines, then implementing multimedia computer conferencing would be more straightforward and consistent between machines.

c. Enhancements to the Prototype Multimedia Computer Conferencing System

(1) Object Manipulation Applications. The engineering and science communities would benefit greatly from programs which allow people to translate, scale, and rotate objects or components thereof interactively. This is already feasible on a system such as the IRIS, but a standard method of hierarchically defining and referring to objects (such

as the proposed PHIGS standard) is required to allow a large number of people on different workstations to utilize this capability.

(2) Speech Recognition and Synthesis. Although typical workstations do not possess sound digitizing, playback, and speech recognition/synthesis capabilities, many microcomputers do and it is feasible to connect a microcomputer to a workstation to handle the audio medium. The advantage of speech over a text window is that the user can be looking at graphics being transmitted by another user and receiving other information by listening, thereby increasing the overall bandwidth of information transfer over that of only text.

APPENDIX A

UNIX 4.2 BSD COMMUNICATIONS PACKAGE LISTING

This appendix contains source code, written in the C language, which enables communications to be established between processes executing on two UNIX systems (4.2 BSD and/or System V). The source for UNIX 4.2 BSD is provided in this appendix for systems programmers interested in understanding how to utilize the UNIX intersystem communications functions. It is not necessary for applications programmers to know the details of these programs in order to use them to establish communications between programs on different systems. Only the calling conventions for the connect_server, connect_client, and write_immediate() functions need to be understood.

```
/*

Program segment net4.2.c
Version 19 November 1986

This segment, when linked into a program on a computer with a
UNIX 4.2 BSD operating system, will allow the program to
communicate with programs executing on other computer systems
over an Internet network.

*/

#define TRUE 1

/* include files for UNIX 4.2 BSD */

#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <netdb.h>

/*************************************************************
```

```
The connect_server(remote_client_name, port_number) function
performs the actions required to connect a server system to a
remote client system

**********************************************************/


int connect_server(remote_client_name, port_number)

   /* name and port number of the remote client system */
   char remote_client_name[];
   int  port_number;

   {

   /* pointer to the remote client system's name */
   char *ptr_client_name;

   /* local socket number */
   int local_server_socket;

   /* function that opens a socket */
   int socket();

   /* function that accepts a connection from a remote client
      socket */
   int accept();

   /* socket number of the remote client system */
   int remote_client_socket;

   /* protocol and address data structure specified for the
      socket */
   static struct sockaddr_in address  = { AF_INET };

   /* address of the remote client system */
   long remote_client_address;

   /* port number of the remote client system */
   short remote_client_port;

   /* size of the address data structure of the remote client
      system */
   int address_size;


   /* begin the process of attempting to connect to the
      remote client system */

   /* get a pointer to the remote client system's name */
   ptr_client_name = &remote_client_name[0];
```

```
/* convert the remote client system name to its address */
remote_client_address =
   (long)gethostbyname(&ptr_client_name);

/* initialize the remote client port number above the
   system reserved ports */
remote_client_port = IPPORT_RESERVED + 1;

/* add the remote client port number to the number of
   reserved ports */
remote_client_port = remote_client_port + port_number;

/* initialize the remote client socket number to an
   invalid value */
remote_client_socket = -1;

/* remote client system address family (Internet in this
   case) */
address.sin_family = AF_INET ;

/* place the remote client port number into the address
   data structure */
address.sin_port = remote_client_port;

/* put the port number in network byte order */
address.sin_port = htons(address.sin_port);

/* place the remote client system's address in the address
   data structure */
address.sin_addr.s_addr = remote_client_address;

/* find number of bytes in the remote client address */
address_size = sizeof(remote_client_address);

/* attempt to open a local socket */
local_server_socket = socket(AF_INET,SOCK_STREAM,0);

if(local_server_socket < 0)
   {
   /* the server couldn't open a local socket */
   perror("Server couldn't open a local socket:");
   }

else
   {

   if(bind(local_server_socket, (caddr_t)&address,
           sizeof(address)) < 0)
      {
      perror("Server couldn't bind address to local
```

```
                socket: ");
        }

    /* set the maximum number of remote client systems to
       be connected to */
    listen(local_server_socket,5);

    printf("Server waiting to connect to
            %s\n",remote_client_name);

    /* attempt to accept a connection */
    remote_client_socket =
       accept(local_server_socket, &address,
              &address_size);

    if(remote_client_socket < 0)
       {
       /* an error occurred in the server attempting to
          accept a connection from remote client system */
       perror("Server couldn't accept a connection from the
               remote client system: ");

       close(local_server_socket);
       }
    else
       {
       /* the server accepted a connection from the remote
          client system */
       break;
       }

    } /* end else local_server_socket >= 0 */


 /* return the socket number of the remote client system */
 return(remote_client_socket);

 } /* end of function connect_server() */



/************************************************************

The connect_client(remote_server_name port_number) function
performs all the actions required to connect a client system
to a remote server system

************************************************************/

int connect_client(remote_server_name, port_number)
```

```
/* name and port number of the remote server system */
char remote_server_name[];
int  port_number;

{

/* pointer to the name of the remote server system */
char *ptr_server_name;

/* local socket number */
int local_client_socket;

/* function that opens a socket */
int socket();

/* function that connects local socket to remote server
   socket */
int connect();

/* the socket number on the remote server system  */
int remote_server_socket;

/* the protocol and address data structure specified for
   the socket */
static struct sockaddr_in address = { AF_INET };

/* address of the remote server system */
struct hostent *remote_server_address;

/* port number of remote system */
short remote_server_port;


/* begin the process of attempting to connect to the
   remote server system */

/* establish ptr to the remote server name */
ptr_server_name = &remote_server_name[0];

/* convert the name of the remote server system to an
   address */
remote_server_address = gethostbyname(ptr_server_name);

/* clear out the address structure */
bzero((char *)&address, sizeof(address));

/* copy the remote server address structure into the
   address structure */
bcopy(remote_server_address->h_addr,
      (char *)&address.sin_addr,
```

```
      remote_server_address->h_length);

/* initialize remote server port number above the system
   reserved ports */
remote_server_port = IPPORT_RESERVED + 1;

/* add the user's remote server port number to the number
   of reserved ports */
remote_server_port = remote_server_port + port_number;

/*  remote server system address family(Internet in this
    case) */
address.sin_family = AF_INET;

/* place the remote server port number into the address
   structure */
address.sin_port = remote_server_port;

/* put the port number in network byte order */
address.sin_port = htons(address.sin_port);

/* attempt to obtain a local socket */
local_client_socket = socket(AF_INET, SOCK_STREAM, 0);

if(local_client_socket < 0)
   {
   /* the client couldn't open a local socket */
   perror("Client couldn't open a local socket: ");
   }
else
   {
   /* place Internet address family type in address
      structure */
   address.sin_family = AF_INET;

   /* attempt to connect local client socket to remote
      server socket */
   remote_server_socket =
      connect(local_client_socket, (caddr_t)&address,
              sizeof(address));

   if(remote_server_socket < 0)
      {
      /* an error occurred in attempting to connect to
         the remote server socket */
      perror("Client couldn't connect to the remote
              server socket: ");
      close(local_client_socket);
      }
   else
      {
```

```
            /* successfully connected to the remote server
               system */
            printf("Connection established with
                    %s.\n",remote_server_name);
            break;
            }

         } /* end else socket >= 0 */

      /* return the socket number of the local client system */
      return(local_client_socket);

      } /* end of funcition connect_client() */


/*************************************************************

function write_immediate(socket_number,buffer,nbytes) writes
to the network connection by forking a child process which
actually performs the write operation.

*************************************************************/


int write_immediate(socket_number, buffer_pointer, nbytes)

      /* socket number to be written */
      int socket_number;

      /* buffer of bytes to be written */
      char buffer[];

      /* the number of bytes to be written */
      long nbytes;

      {

      /* function which initiates a child process */
      int fork();

      /* value returned from routine fork()  */
      int forkval;


      /* initiate a child process which will perform the write
         operation */
      forkval = fork();

      /* determine whether a child process was successfully
         started */
      if(forkval == 0)
```

```
    {
    /* attempt to perform the write operation */
    while(write(local_socket,buffer,nbytes) != nbytes)
       {
       /* attempt to write the buffer contents */
       }
    /* terminate the child process after the buffer is
       successfully written */
    exit(1);
    }
else
    /* an error occurred in starting the child process */
    {
    perror("Error occurred while attempting to fork a
            write-immediate process: ");
    /* return an error value to the application */
    return(-1);
    }
/* return a value indicating successful operation */
return(forkval);
} /* end of write_immediate() function */
```

APPENDIX B

UNIX SYSTEM V COMMUNICATIONS PACKAGE LISTING

This appendix contains source code, written in the C language, which enables communications to be established between processes executing on two UNIX systems (4.2 BSD and/or System V). The source for UNIX System V is provided in this appendix for systems programmers interested in understanding how to utilize the UNIX intersystem communications functions. It is not necessary for applications programmers to know the details of these programs in order to use them to establish communications between programs on different systems. Only the calling conventions for the connect_server, connect_client, and write_immediate() functions need to be understood.

```
/*

Program segment netV.c
Version 03 November 1986

Link with IRIS system library file /usr/lib/libsocket.a

This segment, when linked into a program on a computer with a
UNIX System V operating system, will allow the program to
communicate with programs executing on other computer systems
over an Internet network.

*/

#define TRUE 1

/* include files for IRIS UNIX System V */

#include "/usr/include/EXOS/sys/socket.h"
#include "/usr/include/EXOS/netinet/in.h"


/*************************************************************
```

```
The connect_server(remote_client_name, port_number) function
performs the actions required to connect a server system to a
remote client system

**********************************************************/


int connect_server(remote_client_name, port_number)

   /* name and port number of the remote client system */
   char remote_client_name[];
   int  port_number;

   {

   /* pointer to the remote client system's name */
   char *ptr_client_name;

   /* local socket number */
   int local_server_socket;

   /* function that returns the address of the remote client
      system */
   long rhost();

   /* function that opens a socket */
   int socket();

   /* function that accepts a connection from a remote client
      socket */
   int accept();

   /* socket number of the remote client system */
   int remote_client_socket;

   /* protocol and address data structure specified for the
      socket */
   static struct sockaddr_in address  = { AF_INET };

   /* address of the remote client system */
   long remote_client_address;

   /* port number of the remote client system */
   short remote_client_port;

   /* size of the address data structure of the remote client
      system */
   int address_size;

   /* options word passed to socket() function */
```

```
int options;


/* begin the process of attempting to connect to the
   remote client system */

 /* initialize the options  */
options =  SO_ACCEPTCONN;

/* get a pointer to the remote client system's name */
ptr_client_name = &remote_client_name[0];

/* convert the remote client system name to its address */
remote_client_address = rhost(&ptr_client_name);

/* initialize the remote client port number above the
   system reserved ports */
remote_client_port = IPPORT_RESERVED + 1;

/* add the remote client port number to the number of
   reserved ports */
remote_client_port = remote_client_port + port_number;

/* initialize the remote client socket number to an
   invalid value */
remote_client_socket = -1;

/* remote client system address family (Internet in this
   case) */
address.sin_family = AF_INET ;

/* place the remote client port number into the address
   data structure */
address.sin_port = remote_client_port;

/* put the port number in network byte order */
address.sin_port = htons(address.sin_port);

/* place the remote client system's address in the address
   data structure */
address.sin_addr.s_addr = remote_client_address;

/* find number of bytes in the remote client address */
address_size = sizeof(remote_client_address);

/* attempt to open a local socket */
   local_server_socket =
      socket(SOCK_STREAM, (struct sockproto *)0, &address,
             options);
```

```
   if(local_server_socket < 0)
      {
      /* the server couldn't open a local socket */
      perror("Server couldn't open a local socket:");
      }

   else
      {

      printf("Server waiting to connect to
              %s\n",remote_client_name);

      /* attempt to accept a connection */
      remote_client_socket =
         accept(local_server_socket, &address);

      if(remote_client_socket < 0)
         {
         /* an error occurred in the server attempting to
            accept a connection from remote client system */
         perror("Server couldn't accept a connection from the
                 remote client system: ");

         close(local_server_socket);
         }
      else
         {
         /* the server accepted a connection from the remote
            client system */
         break;
         }

      } /* end else local_server_socket >= 0 */


   /* return the socket number of the remote client system */
   return(local_server_socket);

   } /* end of function connect_server() */



/*************************************************************

The connect_client(remote_server_name port_number) function
performs all the actions required to connect a client system
to a remote server system

*************************************************************/
```

```
int connect_client(remote_server_name, port_number)

   /* name and port number of the remote server system */
   char remote_server_name[];
   int  port_number;

   {

   /* pointer to the name of the remote server system */
   char *ptr_server_name;

   /* local socket number */
   int local_client_socket;

   /* function that opens a socket */
   int socket();

   /* function that connects local socket to remote server
      socket */
   int connect();

   /* function that returns the remote server system's
      address given a name - this is a System V function */
   long rhost();

   /* the socket number on the remote server system  */
   int remote_server_socket;

   /* the protocol and address data structure specified for
      the socket */
   static struct sockaddr_in address = { AF_INET };

   /* address of the remote server system */
   struct hostent *remote_server_address;

   /* port number of remote system */
   short remote_server_port;

   /* options word passed to socket() function */
   int options;


   /* begin the process of attempting to connect to the
      remote server system */

   /* maintain socket as long as possible */
   options =  SO_KEEPALIVE ;

   /* establish ptr to the remote server name */
   ptr_server_name = &remote_server_name[0];
```

```
/* convert the name of the remote server system to an
   address */
remote_server_address = rhost(&ptr_server_name);


/* initialize remote server port number above the system
   reserved ports */
remote_server_port = IPPORT_RESERVED + 1;

/* add the user's remote server port number to the number
   of reserved ports */
remote_server_port = remote_server_port + port_number;

/*  remote server system address family(Internet in this
    case) */
address.sin_family = AF_INET;

/* place the remote server port number into the address
   structure */
address.sin_port = remote_server_port;

/* put the port number in network byte order */
address.sin_port = htons(address.sin_port);

/* attempt to obtain a local socket */
local_client_socket =
   socket(SOCK_STREAM, (struct sockproto *)0, &address,
          options);

if(local_client_socket < 0)
   {
   /* the client couldn't open a local socket */
   perror("Client couldn't open a local socket: ");
   }
else
   {
   /* place Internet address family type in address
      structure */
   address.sin_family = AF_INET;

   /* attempt to connect local client socket to remote
      server socket */
   remote_server_socket =
      connect(local_client_socket, &address);

   if(remote_server_socket < 0)
      {
      /* an error occurred in attempting to connect to
         the remote server socket */
      perror("Client couldn't connect to the remote
              server socket: ");
```

```
            close(local_client_socket);
            }
         else
            {
            /* successfully connected to the remote server
               system */
            printf("Connection established with
                    %s.\n",remote_server_name);
            break;
            }

         } /* end else socket >= 0 */

      /* return the socket number of the local client system */
      return(local_client_socket);

      } /* end of funcition connect_client() */


/*************************************************************

function write_immediate(socket_number,buffer,nbytes) writes
to the network connection by forking a child process which
actually performs the write operation.

*************************************************************/


int write_immediate(socket_number, buffer_pointer, nbytes)

      /* socket number to be written */
      int socket_number;

      /* buffer of bytes to be written */
      char buffer[];

      /* the number of bytes to be written */
      long nbytes;

      {

      /* function which initiates a child process */
      int fork();

      /* value returned from routine fork()  */
      int forkval;


      /* initiate a child process which will perform the write
         operation */
      forkval = fork();
```

```
/* determine whether a child process was successfully
   started */
if(forkval == 0)
   {
   /* attempt to perform the write operation */
   while(write(local_socket,buffer,nbytes) != nbytes)
      {
      /* attempt to write the buffer contents */
      }
   /* terminate the child process after the buffer is
      successfully written */
   exit(1);
   }
else
   /* an error occurred in starting the child process */
   {
   perror("Error occurred while attempting to fork a
           write-immediate process: ");
   /* return an error value to the application */
   return(-1);
   }
/* return a value indicating successful operation */
return(forkval);
} /* end of write_immediate() function */
```

APPENDIX C

INTERTEXT PROGRAM LISTING

The source code for the Intertext program is contained in this appendix. It is written in the C language for UNIX systems. If a workstation with multiple programming shell windows is available, this program can be executed in a number of these windows simultaneously. This allows a user to participate in or monitor one or more conferences at one time.

```
/*

Program intertext.c
Version 04 November 1986

This program allows a user on a UNIX terminal to send
messages to another user on another UNIX terminal.

Link the object code from compiling this source file with
object file net4.2.o or netV.o.

*/

#include <stdio.h>
#define TRUE 1
#define FALSE 0

main()
   {
   /* socket number of the local system */
   int user_socket;

   /* function which connects a local server system to a
      remote client system */
   int connect_server();

   /* function which connects a local client system to a
      remote server system */
   int connect_client();

   /* client/server status input variable */
   char *client_server;
```

```
/* Boolean variable indicating client/server status */
int server;
/* name of remote system */
char *remote_system;

/* buffer for messages */
char *buf

/* number of bytes actually read/written and length of
   message buffer */
int nbytes, buflen;


/* program execution begins here */

/* determine remote system name and conference name */
puts("Please type the name of the remote system you
        would like to connect to: ");
gets(remote_system);

/* determine the port number */
puts("Please type the port number you would like to
        connect to: ");
scanf("%d",port_number);

/* determine whether user will be server or client */
puts("Are you initiating a conference or joining an
      existing one (please type I or J): ");
gets(client_server);
if((client_server[0] == 'i') || (client_server[0] == 'I'))
   server = TRUE;
else
   server = FALSE;

if(server == TRUE)
   /* open connection to the remote system as a server */
   user_socket = connect_server(remote_system,
                                port_number);
else
   /* open connection to the remote system as a client */
   user_socket = connect_client(remote_system,
                                port_number);

/* initialize the buffer size to a maximum of 256
   characters */
buflen = 256;

/* loop until the first character of a message is 'q' */
while(buf[0] != 'q')
   {
```

```
   /* if a server read a message and send it */
   if(server == TRUE)
      {
      /* read a line of characters from the user's
      keyboard into the buffer */
      gets(buf);

      /* write the contents of the buffer to the remote
         system */
      nbytes = write(user_socket,buf,buflen);

      /* read a message from the remote system into the
         buffer */
      nbytes = read(user_socket,buf,buflen);

      /* write the contents of the buffer to the screen */
      puts(buf);

      } /* end of if(server == TRUE) */
   else
      {
     /* read a message from the remote system into the
         buffer */
      nbytes = read(user_socket,buf,buflen);

      /* write the contents of the buffer to the screen */
      puts(buf);

      /* read a line of characters from the user's
      keyboard into the buffer */
      gets(buf);

      /* write the contents of the buffer to the remote
         system */
      nbytes = write(user_socket,buf,buflen);

      } /* end of else(server != TRUE) */

   } /* end of while(buf[0] != 'q') */

/* close the connection to the remote system */
close(user_socket);

} /* end of main() */
```

APPENDIX D

INTERDRAW PROGRAM LISTING

The source code for the Interdraw program is contained in this appendix. It is written in the C language for UNIX systems. If a workstation with multiple programming shell windows is available, this program can be executed in a number of these windows simultaneously. This allows a user to participate in or monitor one or more graphics conferences at one time.

```
/*

This is program Interdraw.c
Version 9 Dec 86

Interdraw.c is an IRIS-2400 program that allows two people on
two IRIS workstations to draw in a window which is displayed
on both of their graphics screens simultaneously.

Run this program under "mex," the Window Manager for the IRIS
by typing "mex", pressing the return key, and then typing
"interdraw."  Answer the questions about the remote system,
port number, and type "I" to initiate.  Then have another
user do the same procedure on another IRIS, answering "J" to
join.  A window will be drawn and filled with light blue
(cyan).  Move the cursor into the window and press the right
mouse button once.  Then move the cursor with the mouse to
move a "rubber band" line.  Draw a line by pressing the left
mouse button, move the origin of the line by pressing the
middle mouse button, and quit by pressing the right mouse
button.  Your lines will be drawn in red, while the other
user's lines will be drawn in blue.

Consult the IRIS 2400 User's Manual for details about the
graphics routines used in this program.

Link the object code from compiling this source file with
object file netV.o.

*/
```

```
/* include the IRIS graphics and device libraries */
#include "gl.h"
#include "device.h"

/* define the window world coordinate system */
#define WXMIN 0.0
#define WXMAX 1023.0
#define WYMIN 0.0
#define WYMAX 767.0

/* define command constants */
#define NOACTION 0
#define QUIT 999

   /* socket number of the local system */
   int user_socket;

   /* function which connects a local server system to a
      remote client system */
   int connect_server();

   /* function which connects a local client system to a
      remote server system */
   int connect_client();

   /* client/server status input variable */
   char *client_server;

   /* Boolean variable indicating client/server status */
   int server;

   /* name of remote system */
   char *remote_system;

   /* record of the last action taken */
   long local_action, remote_action;

   /* buffer for passed data */
   float buf[3];

   /* declare object names */
   Object local_single_line;
   Object local_accumulative;
   Object remote_single_line;
   Object remote_accumulative;

   /* declare tag names */
   Tag local_movetag,local_drawtag;
   Tag remote_movetag,remote_drawtag;

   /* x,y coords of local and remote lines */
```

```
    float local_x,local_y;
    float remote_x,remote_y;

    /* window origin, size, and cursor initial position */
    long origin_x, origin_y;
    long size_x, size_y;
    long init_x, init_y;

    /* writemask value */
    Colorindex wmask;

    /* mouse and button values */
    short value, value_x, value_y;

    /* mouse, button, and redraw device detection variables */
    Device active_device, temp_device;

    /* window identifier */
    int drawing_window;

    /* number of bytes actually written/read during a write or
       read operation */
    int nbytes;


main()
    {
    /* program execution begins here */

    /* determine remote system name and conference name */
    puts("Please type the name of the remote system you
            would like to connect to: ");
    gets(remote_system);

    /* determine the port number */
    puts("Please type the port number you would like to
            connect to: ");
    scanf("%d",port_number);

    /* determine whether user will be server or client */
    puts("Are you initiating a conference or joining an
          existing one (please type I or J): ");
    gets(client_server);
    if((client_server[0] == 'i') || (client_server[0] == 'I'))
       server = TRUE;
    else
       server = FALSE;

    if(server == TRUE)
       /* open connection to the remote system as a server */
       user_socket = connect_server(remote_system,
```

```
                                    port_number);
else
   /* open connection to the remote system as a client */
   user_socket = connect_client(remote_system,
                                    port_number);

/* initialize values for x,y */
local_x = WXMIN + (WXMAX - WXMIN)/2.0;
local_y = WYMIN + (WYMAX - WYMIN)/2.0;
remote_x = WXMIN + (WXMAX - WXMIN)/2.0;
remote_y = WYMIN + (WYMAX - WYMIN)/2.0;

/* initialize and open an IRIS Window Manager window */
prefposition(255,768,192,576);
foreground();
drawing_window = winopen("drawing_window");
wintitle("Drawing Window");

/* allow the user to move and resize the window */
winset(drawing_window);
winconstraints();

/* put the IRIS into double buffer mode */
doublebuffer();

/* configure the IRIS (means use the above command
   settings) */
gconfig();

/* enable all the bit planes for writing */
/* sets to 2**(getplanes()) minus one (all bits on) */
wmask = ((1<<getplanes()) -1);
writemask(wmask);

/* Full screen viewport */
viewport(0,1023,0,767);

/* orthogonal projection 2D for the world coord sys */
ortho2(0.0,1023.0,0.0,767.0);

/* determine initial size and location of the window */
getsize(&size_x, &size_y);
getorigin(&origin_x, &origin_y);

/* determine the center of the window */
init_x = origin_x + size_x/2;
init_y = origin_y + size_y/2;

/* set initial value and range limit for mouse */
setvaluator(MOUSEX,init_x,0,1023);
setvaluator(MOUSEY,init_y,0,767);
```

```
/* queue redraw events */
qdevice(REDRAW);

/* queue mouse button events */
qdevice(MOUSE1);
qdevice(MOUSE2);
qdevice(MOUSE3);
qdevice(MOUSEX);
qdevice(MOUSEY);

/* record mouse x and y coordinates on the device queue
   whenever the middle or right mouse buttons are
   pressed */
tie(MOUSE2,MOUSEX,MOUSEY);
tie(MOUSE3,MOUSEX,MOUSEY);

/* generate the local single line object */
local_single_line = genobj();

/* define the local single line object */
makeobj(local_single_line);

   /* make the lines 3 pixels thick */
   linewidth(3);

   /* generate and store a tag for moving the local single
   line starting point */
   local_movetag = gentag();
   maketag(local_movetag);

   /* move the local single line starting point */
   move2(local_x,local_y);

   /* generate and store a tag for moving the local single
   line ending point */
   local_drawtag = gentag();
   maketag(local_drawtag);

   /* move the local single line ending point */
   draw2(local_x,local_y);

closeobj();

/* generate the remote single line object */
remote_single_line = genobj();

/* define the remote single line object */
makeobj(remote_single_line);

   /* make the lines 3 pixels thick */
```

```
    linewidth(3);

    /* generate and store a tag for moving the remote
    single line starting point */
    remote_movetag = gentag();
    maketag(remote_movetag);

    /* move the remote single line starting point */
    move2(remote_x,remote_y);

    /* generate and store a tag for moving the local single
    line ending point */
    remote_drawtag = gentag();
    maketag(remote_drawtag);

    /* move the remote single line ending point */
    draw2(remote_x,remote_y);

closeobj();

/* generate the object which holds the accumulated
   local drawing */
local_accumulative = genobj();

/* define the local accumulative object */
makeobj(local_accumulative);

    /* make the lines 3 pixels thick */
    linewidth(3);

  /* add a move to the local accumulative object */
  move2(local_x,local_y);

closeobj();

/* generate the object which holds the accumulated
   remote drawing */
remote_accumulative = genobj();

/* define the remote accumulative object */
makeobj(remote_accumulative);

    /* make the lines 3 pixels thick */
    linewidth(3);

    /* add a move to the remote accumulative object */
    move2(remote_x,remote_y);

closeobj();

/* turn on the default cursor */
```

```
setcursor(0,RED,wmask);

/* attach the cursor to the mouse */
attachcursor(MOUSEX,MOUSEY);

/* turn the cursor on */
curson();

/* if a server system, start communications by sending a
   record to the remote system */
if(server == TRUE)
   {
   buf[0] = local_action;
   buf[1] = local_x;
   buf[2] = local_y;
   nbytes = write(server_socket,buf,3*sizeof(float));
   }

/* main loop */
while(TRUE)
   {
   /* process queue data */
   while(qtest() != 0)
      {
      /* read a value from the queue */
      active_device = qread(&value);

      /* determine whether a window has been moved */
      if(active_device == REDRAW)
         {
         reshapeviewport();
         getorigin(&origin_x,&origin_y);
         getsize(&size_x, &size_y);

         init_x = ((size_x - 1)/(WXMAX - WXMIN)) *
                  (local_x - WXMIN) + origin_x;
         init_y = ((size_y - 1)/(WYMAX - WYMIN)) *
                  (local_y - WYMIN) + origin_y;

         setvaluator(MOUSEX, init_x, 0, 1023);
         setvaluator(MOUSEY, init_y, 0, 767);
         }


      /* start out by saying no action has occurred */
      local_action = NOACTION;

      /* should we start a new line? */
      if(active_device == MOUSE2)
         {
         /* middle mouse button pressed */
```

```
            local_action = MOUSE2;

            /* start a new line at the cursor position */
            /* dont add the dragged line to local
               accumulative object */
            /* read mouse x and y values from the queue */
            temp_device = qread(&value_x);
            temp_device = qread(&value_y);

            local_x = ((WXMAX - WXMIN)/(size_x - 1)) *
                      (value_x - origin_x) + WXMIN;
            local_y = ((WYMAX - WYMIN)/(size_y - 1)) *
                      (value_y - origin_y) + WYMIN;

            /* update the local single line object */
            editobj(local_single_line);

               objreplace(local_movetag);
               move2(local_x,local_y);

               objreplace(local_drawtag);
               draw2(local_x,local_y);

            closeobj();

/* add move2 command to the local accumulative object */
editobj(local_accumulative);

   move2(local_x,local_y);

closeobj();

            }

         /* should we add a line to the local accumulative
            object? */
         if(active_device == MOUSE3)
            {

            /* left mouse button pressed */
            local_action = MOUSE3;

            /* add line to the local_accumulative object */
            temp_device = qread(&value_x);
            temp_device = qread(&value_y);

            local_x = ((WXMAX - WXMIN)/(size_x - 1)) *
                      (value_x - origin_x) + WXMIN;
            local_y = ((WYMAX - WYMIN)/(size_y - 1)) *
                      (value_y - origin_y) + WYMIN;
```

```
      /* add the current line to the local accumulative
         object */
      editobj(local_accumulative);

         draw2(local_x,local_y);

      closeobj();

      /* write x,y over local_movetag of single line
         object */
      editobj(local_single_line);

         objreplace(local_movetag);
         move2(local_x,local_y);

      closeobj();

      }

   /* if mouse is moved in the x direction */
   if(active_device == MOUSEX)
      {
      local_x = ((WXMAX - WXMIN)/(size_x - 1)) *
                (value - origin_x) + WXMIN;

      /* update the endpoint of the current line */
      editobj(local_single_line);

         objreplace(local_drawtag);
         draw2(local_x,local_y);

      closeobj();
      }

   /* if mouse is moved in the y direction */
   if(active_device == MOUSEY)
      {
      local_y = ((WYMAX - WYMIN)/(size_y - 1)) *
                (value - origin_y) + WYMIN;

      /* update the endpoint of the current line */
      editobj(local_single_line);

         objreplace(local_drawtag);
         draw2(local_x,local_y);

      closeobj();
      }


   } /* end if(qtest() != 0) */
```

```
/* redraw the entire window's contents */

/* clear the window to cyan */
color(CYAN);
clear();

/* receive a record from the remote system */
nbytes = read(server_socket,buf,3*sizeof(float));
remote_action = buf[0];
remote_x = buf[1];
remote_y = buf[2];

switch(remote_action)
   {

   case QUIT:

      /* quit because right mouse button was pressed */
      break;

   case MOUSE2:

      /* start a new line at the cursor position */
      /* dont add the dragged line to accumulative */
      editobj(remote_single_line);

         objreplace(remote_movetag);
         move2(remote_x,remote_y);

         objreplace(remote_drawtag);
         draw2(remote_x,remote_y);

      closeobj();

      /* add move2 command to accumulative object */
      editobj(remote_accumulative);

         move2(remote_x,remote_y);

      closeobj();

      break;

   case MOUSE3:

      /* add line to the accumulative object */

      editobj(remote_accumulative);

         draw2(remote_x,remote_y);
```

```
      closeobj();

      /* write x,y over movetag of single line
         object */
      editobj(remote_single_line);

         objreplace(remote_movetag);
         move2(remote_x,remote_y);

      closeobj();

      break;

   default:

      break;

   } /* end switch(remote_action) */

/* move the draw part of the remote single line */
editobj(remote_single_line);

   objreplace(remote_drawtag);
   draw2(remote_x,remote_y);

closeobj();

/* draw the remote single line */
color(BLUE);
callobj(remote_single_line);

/* draw the remote accumulative lines buffer */
callobj(remote_accumulative);


/* move the draw part of local single line */
editobj(local_single_line);

   objreplace(local_drawtag);
   draw2(local_x,local_y);

closeobj();

/* draw the local single line */
color(RED);
callobj(local_single_line);

/* draw the local accumulative lines buffer */
callobj(local_accumulative);
```

```
    /* send a record to the remote system */
    buf[0] = local_action;
    buf[1] = local_x;
    buf[2] = local_y;
    nbytes = write(server_socket,buf,3*sizeof(float));

    /* change the graphics buffers for smooth animation */
    swapbuffers();

    /* quit if right mouse button is pressed */
    if(active_device == MOUSE1)
       {
       buf[0] = QUIT;
       write(server_socket,buf,3*sizeof(float));
       break;
       }

    /* if remote system quits then quit also */
    if(remote_action == QUIT)
       {
       break;
       }

    } /* end of while(TRUE) */

/* perform some clean-up by setting graphics to black */
color(BLACK);
clear();
swapbuffers();
clear();
curson();
textinit();
swapbuffers();
finish();

/* graphics exit */
gexit();

/* close the network connection */
close(user_socket);

} /* end of main() */
```

LIST OF REFERENCES

1. Sarin, S. and Greif, I., "Computer-Based Real-Time Conferencing Systems," IEEE Computer, p. 34, October 1985.

2. Poggio, A., and others, "CCWS: A Computer-Based, Multimedia Information System," IEEE Computer, pp. 92-103, October 1985.

3. Aguilar, L., "A Format for a Graphical Communications Protocol," IEEE Computer Graphics and Applications, pp. 52-62, March 1986.

4. Shuey, D., Bailey, D., and Morrissey, T., "PHIGS: A Standard, Dynamic, Interactive Graphics Interface," IEEE Computer Graphics and Applications, pp. 50-57, August 1986.

5. Herman, W., "The Cost of Graphics Standards," Computer Graphics World, p. 128, November 1986.

BIBLIOGRAPHY

Apple Computer, Inc., Inside Macintosh, 1985.

Foley, J. and Van Dam, A., Fundamentals of Interactive Computer Graphics, Addison-Wesley, 1982.

International Organization for Standards, GKS-3D Functional Description, ISO Second DP 8805, October 1985.

International Organization for Standards, GKS Functional Description, ISO IS 7942, July 1985.

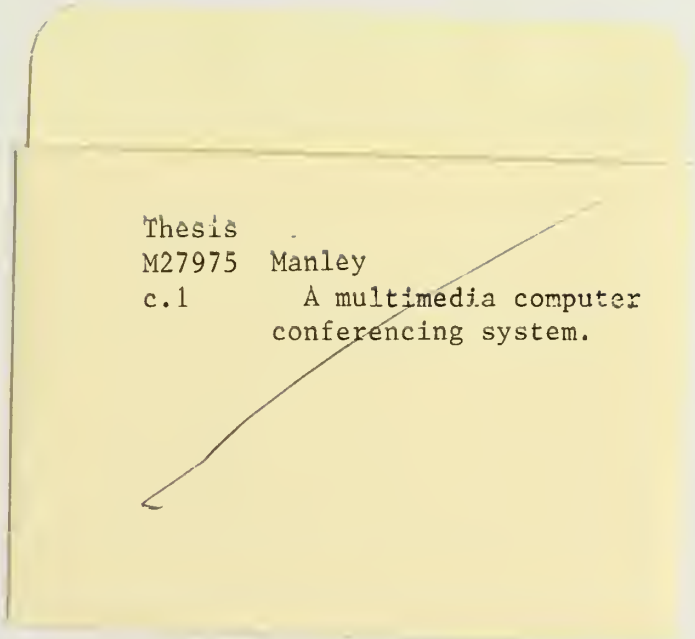
Leffler, S., Fabry, R., and Joy, W., A 4.2 BSD Interprocess Communication Primer, draft documentation for UNIX 4.2 Berkeley Software Distribution, 11 August 1986.

INITIAL DISTRIBUTION LIST

	No. Copies
1. Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2. Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3. Chairman, Code 52 Department of Computer Science Naval Postgraduate School Monterey, California 93943-5000	1
4. Computer Technology Curricular Officer, Code 37 Naval Postgraduate School Monterey, California 93943-5000	1
5. Dr. Michael J. Zyda, Code 52Zk Department of Computer Science Naval Postgraduate School Monterey, California 93943-5000	1
6. LCDR James E. Manley 12465 Hedges Run Drive Woodbridge, VA 22192	1

17898 2

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93943-5



thesM27975
A multimedia computer conferencing syste
3 2768 000 70772 3
DUDLEY KNOX LIBRARY